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Appr. February 20, 1998 *Attorney for Applicant*

VERIFIED TRANSLATION OF JAPANESE PATENT APPLICATION NO. 11-161329

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Attached is a verified English translation of Japanese Patent Application No. 11-161329, which is the foreign priority document for the above-named U.S. Patent Application. Japanese Patent Application No. 11-161329 was originally filed in Japan on June 8, 1999.

Respectfully submitted,

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I, Tadahiko Itoh, a Patent Attorney of Tokyo, Japan having my office at 32nd Floor, Yebisu Garden Place Tower, 20-3 Ebisu 4-Chome, Shibuya-Ku, Tokyo 150-6032, Japan do solemnly and sincerely declare that I am the translator of the attached English language translation and certify that the attached English language translation is a correct, true and faithful translation of Japanese Patent Application No. 11-161329 to the best of my knowledge and belief.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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This is to certify that the annexed is a true copy of the following application as filed with this office.

Date of Application: June 8, 1999

Application Number: Japanese Patent Application No. 11-161329

Applicant(s) FUJITSU LIMITED

August 30, 1999

Commissioner,
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DOCUMENT NAME

SPECIFICATION

TITLE OF THE INVENTION

MAGNETIC RECORDING MEDIUM AND MAGNETIC STORAGE APPARATUS

PATENT CLAIMS

1. A magnetic recording medium comprising:

at least one exchange layer structure; and

a magnetic layer formed on said exchange layer structure,

said exchange layer structure comprising:

a ferromagnetic layer; and

a non-magnetic coupling layer provided on said ferromagnetic layer and under said magnetic layer,

said ferromagnetic layer and said magnetic layer having antiparallel magnetizations.

2. The magnetic recording medium as claimed in claim 1, wherein said ferromagnetic layer is made of a material selected from a group consisting of Co, Ni, Fe, Ni-based alloys, Fe-based alloys, and Co-based alloys including CoCrTa, CoCrPt and CoCrPt-M, where M = B, Mo, Nb, Ta, W or alloys thereof.

3. The magnetic recording medium as claimed in claim 1 or 2, wherein said ferromagnetic layer has a thickness in a range of 2 to 10 nm.

4. The magnetic recording medium as claimed in any of claims 1 to 3, wherein said non-magnetic coupling layer is made of a material selected from a group of Ru, Rh, Ir, Ru-based alloys,

Rh-based alloys, and Ir-based alloys.

5. The magnetic recording medium as claimed in any of claims 1 to 4, wherein said non-magnetic coupling layer has a thickness in a range of 0.4 to 0.9 nm.

6. The magnetic recording medium as claimed in any of claims 1 to 5, wherein said magnetic layer is made of a material selected from a group of Co, and Co-based alloys including CoCrTa, CoCrPt and CoCrPt-M, where M = B, Mo, Nb, Ta, W or alloys thereof.

7. The magnetic recording medium as claimed in any of claims 1 to 6, which further comprises:

a substrate; and

an underlayer provided above said substrate,

said exchange layer structure being provided above said underlayer.

8. The magnetic recording medium as claimed in claim 7, which further comprises:

a non-magnetic intermediate layer interposed between said underlayer and said exchange layer structure,

said non-magnetic intermediate layer having a hcp structure alloy selected from a group of CoCr-M, where M = B, Mo, Nb, Ta, W or alloys thereof, and having a thickness in a range of 1 to 5 nm.

9. The magnetic recording medium as claimed in claim 7 or 8, which further comprises:

a NiP layer interposed between said substrate and said underlayer, said NiP layer being mechanically textured or oxidized.

10. The magnetic recording medium as claimed in any of claims 7 to 9, wherein said underlayer is made of a B2 structure alloy selected from a group of NiAl and FeAl.

11. The magnetic recording medium as claimed in any of claims 1 to 10, which comprises at least a first exchange layer structure and a second exchange layer structure interposed between said first exchange layer structure and said magnetic layer, wherein a ferromagnetic layer of said second exchange layer structure has a magnetic anisotropy lower than that of a ferromagnetic layer of said first exchange layer structure, and magnetizations of the ferromagnetic layers of said first and second exchange layer structures are antiparallel.

12. The magnetic recording medium as claimed in any of claims 1 to 11, which comprises at least a first exchange layer structure and a second exchange layer structure interposed between said first exchange layer structure and said magnetic layer, wherein a product of a remanent magnetization and thickness of a ferromagnetic layer of said second exchange layer structure is smaller than that of a ferromagnetic layer of said first exchange layer structure, and magnetizations of the ferromagnetic layers of said first and second exchange layer structures are antiparallel.

13. A magnetic storage apparatus comprising at least one magnetic recording medium according to one of claims 1 to 12.

DETAILED DESCRIPTION OF THE INVENTION

[0001]

TECHNICAL FIELD OF THE INVENTION

The present invention generally relates to magnetic recording media and magnetic storage apparatuses, and more particularly to a magnetic recording medium and a magnetic storage apparatus which are suited for high-density recording.

[0002]

PRIOR ART

The recording density of longitudinal magnetic recording media, such as magnetic disks, has been increased considerably, due to the reduction of medium noise and the development of magnetoresistive and high-sensitivity spin-valve heads. A typical magnetic recording medium is comprised of a substrate, an underlayer, a magnetic layer, and a protection layer which are successively stacked in this order. The underlayer is made of Cr or a Cr-based alloy, and the magnetic layer is made of a Co-based alloy.

[0003]

Various methods have been proposed to reduce the medium noise. For example, Okamoto et al., "Rigid Disk Medium For 5 Gbit/in^2 Recording", AB-3, Intermag '96 Digest proposes decreasing the grain size and size distribution of the magnetic layer by reducing the magnetic layer thickness by the proper use of an underlayer made of CrMo, and a U.S. Patent No.5,693,426 proposes the use of an underlayer made of NiAl. Further, Hosoe et al., "Experimental Study of Thermal Decay in High-Density Magnetic Recording Media", IEEE Trans. Magn. Vol.33, 1528 (1997), for example, proposes the use of an underlayer made of CrTiB. The underlayers described above also promote c-axis orientation of the magnetic layer in a plane which increases the remanence magnetization and the thermal stability of written bits. In addition, proposals have been made to reduce the thickness of the magnetic layer, to

increase the resolution or to decrease the width of transition between written bits. Furthermore, proposals have been made to decrease the exchange coupling between grains by promoting more Cr segregation in the magnetic layer which is made of the CoCr-based alloy.

[0004]

However, as the grains of the magnetic layer become smaller and more magnetically isolated from each other, the written bits become unstable due to thermal activation and to demagnetizing fields which increase with linear density. Lu et al., "Thermal Instability at 10 Gbit/in^2 Magnetic Recording", IEEE Trans. Magn. Vol.30, 4230 (1994) demonstrated, by micromagnetic simulation, that exchange-decoupled grains having a diameter of 10 nm and ratio K_uV/k_BT~60 in 400 kfci di-bits are susceptible to significant thermal decay, where K_u denotes the magnetic anisotropy constant, V denotes the average magnetic grain volume, k_B denotes the Boltzmann constant, and T denotes the temperature. The ratio K_uV/k_BT is also referred to as a thermal stability factor.

[0005]

It has been reported in Abarra et al., "Thermal Stability of Narrow Track Bits in a 5 Gbit/in^2 Medium", IEEE Trans. Magn. Vol.33, 2995 (1997) that the presence of intergranular exchange interaction stabilizes written bits, by MFM studies of annealed 200 kfci bits on a 5 Gbit/in^2 CoCrPtTa/CrMo medium. However, more grain decoupling is essential for recording densities of 20 Gbit/in^2 or greater.

[0006]

The obvious solution has been to increase the magnetic anisotropy of the magnetic layer. But unfortunately, the increased magnetic anisotropy

places a great demand on the head write field which degrades the "overwrite" performance which is the ability to write over previously written data.

In addition, the coercivity of thermally unstable magnetic recording medium increases rapidly with decreasing switching time, as reported in He et al., "High Speed Switching in Magnetic Recording Media", J. Magn. Magn. Mater. Vol.155, 6 (1996), for magnetic tape media, and in J. H. Richter, "Dynamic Coervicity Effects in Thin Film Media", IEEE Trans. Magn. Vol.34, 1540 (1997), for magnetic disk media. Consequently, the adverse effects are introduced in the data rate, that is, how fast data can be written on the magnetic layer and the amount of head field required to reverse the magnetic grains.

[0007]

On the other hand, another proposed method of improving the thermal stability increases the orientation ratio of the magnetic layer, by appropriately texturing the substrate under the magnetic layer. For example, Akimoto et al., "Relationship Between Magnetic Circumferential Orientation and Magnetic Thermal Stability", J. Magn. Magn. Mater. (1999), in press, report through micromagnetic simulation, that the effective ratio K_uV/k_BT is enhanced by a slight increase in the orientation ratio. This further results in a weaker time dependence for the coercivity which improves the overwrite performance of the magnetic recording medium, as reported in Abarra et al., "The Effect of Orientation Ratio on the Dynamic Coercivity of Media for >15 Gbit/in^2 Recording", EB-02, Intermag '99, Korea.

[0008]

Furthermore, keepered magnetic recording media have been proposed for thermal stability improvement. The keeper layer is made up of a

magnetically soft layer parallel to the magnetic layer. This soft layer can be disposed above or below the magnetic layer. Oftentimes, a Cr isolation layer is interposed between the soft layer and the magnetic layer. The soft layer reduces the demagnetizing fields in written bits on the magnetic layer. However, coupling the magnetic layer to a continuously-exchanged coupled soft layer defeats the purpose of decoupling the grains of the magnetic layer. As a result, the medium noise increases.

[0009]

PROBLEMS TO BE SOLVED BY THE INVENTION

Various methods have been proposed to improve the thermal stability and to reduce the medium noise. However, there was a problem in that the proposed methods do not provide a considerable improvement of the thermal stability of written bits, thereby making it difficult to greatly reduce the medium noise. In addition, there was another problem in that some of the proposed methods introduce adverse effects on the performance of the magnetic recording medium due to the measures taken to reduce the medium noise.

[0010]

More particularly, in order to obtain a thermally stable performance of the magnetic recording medium, it is conceivable to (i) increase the magnetic anisotropy constant K_u, (ii) decrease the temperature T or, (iii) increase the grain volume V of the magnetic layer. However, measure (i) increases the coercivity, thereby making it more difficult to write information on the magnetic layer. In addition, measure (ii) is impractical since in magnetic disk drives, for example, the operating temperature may become greater than 60° C. Furthermore, measure (iii) increases the medium noise as described above. As an alternative for

measure (iii), it is conceivable to increase the thickness of the magnetic layer, but this would lead to deterioration of the resolution.

[0011]

Accordingly, an object of the present invention is to provide a magnetic recording medium and a magnetic storage apparatus, which can improve the thermal stability of written bits without increasing the medium noise, so as to enable a reliable high-density recording without introducing adverse effects on the performance of the magnetic recording medium, that is, unnecessarily increasing the magnetic anisotropy.

[0012]

MEANS OF SOLVING THE PROBLEMS

The problem described above may be solved by a magnetic recording medium comprising at least one exchange layer structure, and a magnetic layer formed on the exchange layer structure, where the exchange layer structure comprises a ferromagnetic layer, and a non-magnetic coupling layer provided on the ferromagnetic layer and under the magnetic layer, and the ferromagnetic layer and the magnetic layer have antiparallel magnetizations. According to the magnetic recording medium of the present invention, it is possible to provide a magnetic recording medium which can improve the thermal stability of written bits, so as to enable reliable high-density recording without degrading the overwrite performance.

[0013]

The ferromagnetic layer may be made of a material selected from a group consisting of Co, Ni, Fe, Ni-based alloys, Fe-based alloys, and Co-based alloys including CoCrTa, CoCrPt and CoCrPt-M, where M = B, Mo, Nb, Ta, W or alloys thereof. The ferromagnetic layer may have a thickness in a range

of 2 to 10 nm.

[0014]

The non-magnetic coupling layer may be made of a material selected from a group of Ru, Rh, Ir, Ru-based alloys, Rh-based alloys, and Ir-based alloys. The non-magnetic coupling layer may have a thickness in a range of 0.4 to 0.9 nm.

The magnetic layer may be made of a material selected from a group of Co, and Co-based alloys including CoCrTa, CoCrPt and CoCrPt-M, where M = B, Mo, Nb, Ta, W or alloys thereof. The magnetic layer may have a thickness selected within a range of 5 to 30 nm. The magnetic recording medium may further comprise a substrate; and an underlayer provided above said substrate, where said exchange layer structure is provided above said underlayer. The magnetic recording medium may further comprise a non-magnetic intermediate layer interposed between said underlayer and said exchange layer structure, where said non-magnetic intermediate layer has a hcp structure alloy selected from a group of CoCr-M, where M = B, Mo, Nb, Ta, W or alloys thereof, and has a thickness in a range of 1 to 5 nm. The magnetic recording medium may further comprise a NiP layer interposed between said substrate and said underlayer, where said NiP layer is mechanically textured or oxidized. Further, the underlayer may be made of a B2 structure alloy selected from a group of NiAl and FeAl.

[0015]

The magnetic recording medium may comprise at least a first exchange layer structure and a second exchange layer structure interposed between said first exchange layer structure and said magnetic layer, wherein a ferromagnetic layer of said second exchange layer structure has a magnetic anisotropy lower than that of a ferromagnetic layer

of said first exchange layer structure, and magnetizations of the ferromagnetic layers of said first and second exchange layer structures are antiparallel.

[0016]

The magnetic recording medium may comprise at least a first exchange layer structure and a second exchange layer structure interposed between said first exchange layer structure and said magnetic layer, wherein a product of a remanent magnetization and thickness of a ferromagnetic layer of said second exchange layer structure is smaller than that of a ferromagnetic layer of said first exchange layer structure, and magnetizations of the ferromagnetic layers of said first and second exchange layer structures are antiparallel.

[0017]

The problem described above may also be solved by a magnetic storage apparatus comprising at least one magnetic recording medium described above. According to the magnetic storage apparatus of the present invention, it is possible to provide a magnetic storage apparatus which can improve the thermal stability of written bits, so as to enable a reliable high-density recording without introducing adverse effects on the performance of the magnetic recording medium.

[0018]

FORMS OF REALIZING THE INVENTION

A description will hereinafter be given of embodiments of the present invention, by referring to the drawings.

[0019]

EMBODIMENTS

First, a description will be given of the operating principle of the present invention.

The present invention submits the use of

layers with antiparallel magnetization structures. For example, S. S. P. Parkin, "Systematic Variation of the Strength and Oscillation Period of Indirect Magnetic Exchange Coupling through the 3d, 4d, and 5d Transition Metals", Phys. Rev. Lett. Vol.67, 3598 (1991) describes several magnetic transition metals such as Co, Fe and Ni that are coupled through thin non-magnetic interlayers such as Ru and Rh. On the other hand, a U.S. Patent No.5,701,223 proposes a spin-valve which employs the above described layers as laminated pinning layers to stabilize the sensor.

[0020]

For a particular Ru or Ir layer thickness between two ferromagnetic layers, the magnetizations can be made parallel or antiparallel. For example, for a structure made up of two ferromagnetic layers of different thickness with antiparallel magnetizations, the effective grain size of a magnetic recording medium can be increased without significantly affecting the resolution. A signal amplitude reproduced from such a magnetic recording medium is reduced due to the opposite magnetizations, but this can be rectified by adding another layer of appropriate thickness and magnetization direction, under the laminated magnetic layer structure, to thereby cancel the effect of one of the layers. As a result, it is possible to increase the signal amplitude reproduced from the magnetic recording medium, and to also increase the effective grain volume. Thermally stable written bits can therefore be realized.

[0021]

The present invention increases the thermal stability of written bits by exchange coupling the magnetic layer to another ferromagnetic layer with an opposite magnetization or, by a laminated ferrimagnetic structure. The

ferromagnetic layer or the laminated ferrimagnetic structure is made up of exchange-decoupled grains as the magnetic layer. In other words, the present invention uses an exchange pinning ferromagnetic layer or a ferrimagnetic multilayer to improve the thermal stability performance of the magnetic recording medium.

[0022]

FIG. 1 is a cross sectional view showing an important part of a first embodiment of a magnetic recording medium according to the present invention.

The magnetic recording medium includes a non-magnetic substrate 1, a first seed layer 2, a NiP layer 3, a second seed layer 4, an underlayer 5, a non-magnetic intermediate layer 6, a ferromagnetic layer 7, a non-magnetic coupling layer 8, a magnetic layer 9, a protection layer 10, and a lubricant layer 11 which are stacked in the order shown in FIG. 1.

[0023]

For example, the non-magnetic substrate 1 is made of Al, Al alloy or glass. This non-magnetic substrate 1 may or may not be mechanically textured. The first seed layer 2 is made of Cr or Ti, for example, especially in the case where the non-magnetic substrate 1 is made of glass. The NiP layer 3 is preferably oxidized and may or may not be mechanically textured. The second seed layer 4 is provided to promote a (001) or a (112) texture of the underlayer 5 when using a B2 structure alloy such as NiAl and FeAl for the underlayer 5. The second seed layer 4 is made of an appropriate material similar to that of the first seed layer 2.

[0024]

In a case where the magnetic recording medium is a magnetic disk, the mechanical texturing

provided on the non-magnetic substrate 1 or the NiP layer 3 is made in a circumferential direction of the disk, that is, in a direction in which tracks of the disk extend.

The non-magnetic intermediate layer 6 is provided to further promote epitaxy, narrow the grain distribution of the magnetic layer 9, and orient the anisotropy axes of the magnetic layer 9 along a plane parallel to the recording surface of the magnetic recording medium. This non-magnetic intermediate layer 6 is made of a hcp structure alloy such as CoCr-M, where M = B, Mo, Nb, Ta, W or alloys thereof, and has a thickness in a range of 1 to 5 nm.

[0025]

The ferromagnetic layer 7 is made of Co, Ni, Fe, Co-based alloy, Ni-based alloy, Fe-based alloy or the like. In other words, alloys such as CoCrTa, CoCrPt and CoCrPt-M, where M = B, Mo, Nb, Ta, W or alloys thereof may be used for the ferromagnetic layer 7. This ferromagnetic layer 7 has a thickness in a range of 2 to 10 nm. The non-coupling magnetic layer 8 is made of Ru, Ir, Rh, Ru-based alloy, Ir-based alloy, Rh-based alloy or the like. This non-magnetic coupling layer 8 preferably has a thickness in a range of 0.4 to 0.9 nm, and preferably on the order of approximately 0.8 nm. For this particular thickness range of the non-magnetic coupling layer 8, the magnetizations of the ferromagnetic layer 7 and the magnetic layer 9 are antiparallel. The ferromagnetic layer 7 and the non-magnetic coupling layer 8 form an exchange layer structure.

[0026]

The magnetic layer 9 is made of Co or a Co-based alloys such as CoCrTa, CoCrPt and CoCrPt-M, where M = B, Mo, Nb, Ta, W or alloys thereof. The

magnetic layer 9 has a thickness in a range of 5 to 30 nm. Of course, the magnetic layer 9 is not limited to a single-layer structure, and a multi-layer structure may be used for the magnetic layer 9.

[0027]

The protection layer 10 is made of C, for example. In addition, the lubricant layer 11 is made of an organic lubricant, for example, for use with a magnetic transducer such as a spin-valve head. The protection layer 10 and the lubricant layer 11 form a protection layer structure on the recording surface of the magnetic recording medium.

Obviously, the layer structure under the exchange layer structure is not limited to that shown in FIG. 1. For example, the underlayer 5 may be made of Cr or Cr-based alloy and formed to a thickness in a range of 5 to 40 nm on the substrate 1, and the exchange layer structure may be provided on this underlayer 5.

[0028]

Next, a description will be given of a second embodiment of the magnetic recording medium according to the present invention.

FIG. 2 is a cross sectional view showing an important part of the second embodiment of the magnetic recording medium. In FIG. 2, those parts which are the same as those corresponding parts in FIG. 1 are designated by the same reference numerals, and a description thereof will be omitted.

In this second embodiment of the magnetic recording medium, the exchange layer structure includes two non-magnetic coupling layers 8 and 8-1, and two ferromagnetic layers 7 and 7-1, which form a ferrimagnetic multilayer. This arrangement increases the effective magnetization and signal, since the magnetizations of the two non-magnetic coupling layers 8 and 8-1 cancel each other instead

of a portion of the magnetic layer 9. As a result, the grain volume and thermal stability of magnetization of the magnetic layer 9 are effectively increased. More bilayer structures made up of the pair of ferromagnetic layer and non-magnetic coupling layer may be provided additionally to increase the effective grain volume, as long as the easy axis of magnetization are appropriately oriented for the subsequently provided layers.

[0029]

The ferromagnetic layer 7-1 is made of a material similar to that of ferromagnetic layer 7, and has a thickness range selected similarly to the ferromagnetic layer 7. In addition, the non-magnetic coupling layer 8-1 is made of a material similar to that of the non-magnetic coupling layer 8, and has a thickness range selected similarly to the non-magnetic coupling layer 8. Within the ferromagnetic layers 7-1 and 7, the c-axes are preferably in-plane and the grain growth columnar.

In this embodiment, the magnetic anisotropy of the ferromagnetic layer 7-1 is preferably lower than that of the ferromagnetic layer 7. However, the magnetic anisotropy of the ferromagnetic layer 7-1 may be the same as or, be higher than that of, the ferromagnetic layer 7.

Furthermore, a product of a remanent magnetization and thickness of the ferromagnetic layer 7 may be smaller than that of the ferromagnetic layer 7-1.

FIG. 3 is a diagram showing an in-plane magnetization curve of a single CoPt layer having a thickness of 10 nm on a Si substrate. In FIG. 3, the ordinate indicates the magnetization (emu), and the abscissa indicates the magnetic field (Oe). Conventional magnetic recording media show a behavior similar to that shown in FIG. 3.

[0031]

FIG. 4 is a diagram showing an in-plane magnetization curve of two CoPt layers separated by a Ru layer having a thickness of 0.8 nm, as in the case of the first embodiment of the magnetic recording medium. In FIG. 4, the ordinate indicates the magnetization (Gauss), and the abscissa indicates the magnetic field (Oe). As may be seen from FIG. 4, the loop shows shifts near the magnetic field which indicate the antiparallel coupling.

FIG. 5 is a diagram showing an in-plane magnetization curve of two CoPt layers separated by a Ru layer having a thickness of 1.4 nm. In FIG. 5, the ordinate indicates the magnetization (emu), and the abscissa indicates the magnetic field (Oe). As may be seen from FIG. 5, the magnetizations of the two CoPt layers are parallel.

[0032]

FIG. 6 is a diagram showing an in-plane magnetization curve for two CoCrPt layers separated by a Ru having a thickness of 0.8 nm, as in the case of the second embodiment of the magnetic recording medium. In FIG. 6, the ordinate indicates the magnetization (emu/cc), and the abscissa indicates the field (Oe). As may be seen from FIG. 6, the loop shows shifts near the field which indicate the antiparallel coupling.

From FIGS. 3 and 4, it may be seen that the antiparallel coupling can be obtained by the provision of the exchange layer structure. In addition, it may be seen by comparing FIG. 5 with FIGS. 4 and 6, the non-magnetic coupling layer 8 is desirably in the range of 0.4 to 0.9 nm in order to achieve the antiparallel coupling.

[0033]

Therefore, according to the first and second embodiments of the magnetic recording medium,

it is possible to effectively increase the apparent grain volume of the magnetic layer by the exchange coupling provided between the magnetic layer and the ferromagnetic layer via the non-magnetic coupling layer, without sacrificing the resolution. In other words, the apparent thickness of the magnetic layer is increased with regard to the grain volume of the magnetic layer so that a thermally stable medium can be obtained, and in addition, the actual thickness of the magnetic layer is not increased so that the resolution remains unaffected by the increased "apparent thickness" of the magnetic layer. As a result, it is possible to obtain a magnetic recording medium with reduced medium noise and thermally stable performance.

[0034]

Next, a description will be given of an embodiment of a magnetic storage apparatus according to the present invention, by referring to FIGS. 7 and 8. FIG. 7 is a cross sectional view showing an important part of this embodiment of the magnetic storage apparatus, and FIG. 8 is a plan view showing the important part of this embodiment of the magnetic storage apparatus.

As shown in FIGS. 7 and 8, the magnetic storage apparatus generally includes a housing 13. A motor 14, a hub 15, a plurality of magnetic recording media 16, a plurality of recording-and-reproducing heads 17, a plurality of suspensions 18, a plurality of arms 19, and an actuator unit 20 are provided within the housing 13. The magnetic recording media 16 are mounted on the hub 15 which is rotated by the motor 14. The recording and reproducing head 17 is made up of a reproducing head such as a MR or GMR head, and a recording head such as an inductive head. Each recording and reproducing head 17 is mounted on the tip end of a

corresponding arm 19 via the suspension 18. The arms 19 are moved by the actuator unit 20. The basic construction of this magnetic storage apparatus is known, and a detailed description thereof will be omitted in this specification.

[0035]

This embodiment of the magnetic storage apparatus is characterized by the magnetic recording media 16. Each magnetic recording medium 16 has the structure of the first or second embodiment of the magnetic recording medium described above in conjunction with FIGS. 1 and 2. Of course, the number of magnetic recording media 16 is not limited to three, and only one, two or four or more magnetic recording media 16 may be provided.

The basic construction of the magnetic storage unit is not limited to that shown in FIGS. 7 and 8. In addition, the magnetic recording medium used in the present invention is not limited to a magnetic disk.

[0036]

Further, the present invention is not limited to these embodiments, but various variations and modifications may be made without departing from the scope of the present invention.

[0037]

EFFECTS OF THE INVENTION

Therefore, according to the present invention, it is possible to provide a magnetic recording medium and a magnetic storage apparatus, which can improve the thermal stability of written bits and reduce the medium noise, so as to enable reliable high-density recording without introducing adverse effects on the performance of the magnetic recording medium.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross sectional view showing an important part of a first embodiment of the magnetic recording medium according to the present invention;

FIG. 2 is a cross sectional view showing an important part of a second embodiment of the magnetic recording medium according to the present invention;

FIG. 3 is a diagram showing an in-plane magnetization curve of a single CoPt layer having a thickness of 10 nm on a Si substrate;

FIG. 4 is a diagram showing an in-plane magnetization curve of two CoPt layers separated by a Ru layer having a thickness of 0.8 nm;

FIG. 5 is a diagram showing an in-plane magnetization curve of two CoPt layers separated by a Ru layer having a thickness of 1.4 nm;

FIG. 6 is a diagram showing an in-plane magnetization curve two CoCrPt layers separated by a Ru having a thickness of 0.8 nm;

FIG. 7 is a cross sectional view showing an important part of an embodiment of the magnetic storage apparatus according to the present invention; and

FIG. 8 is a plan view showing the important part of the embodiment of the magnetic storage apparatus.

DESCRIPTION OF THE REFERENCE NUMERALS

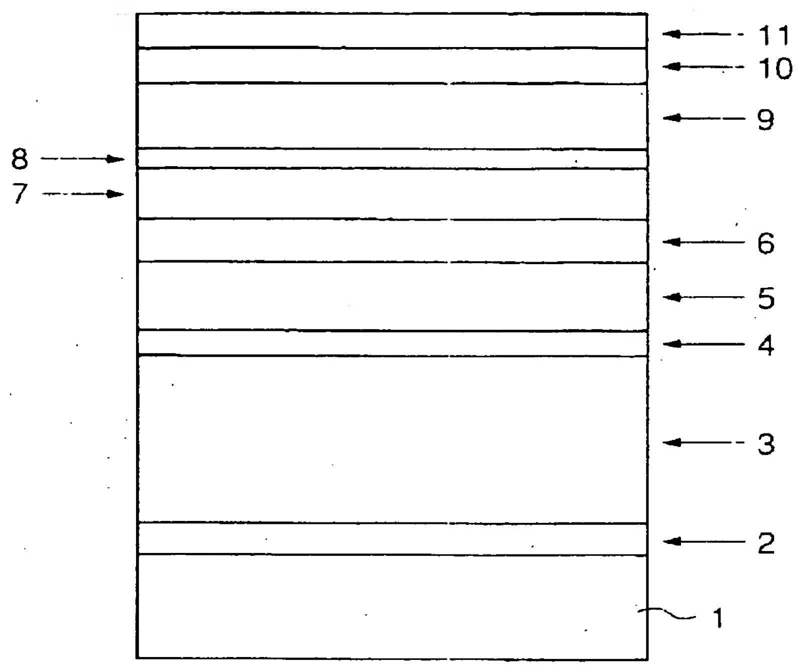
1 substrate
2 first seed layer
3 NiP layer
4 second seed layer
5 underlayer
6 non-magnetic intermediate layer
7, 7-1 ferromagnetic layer
8, 8-1 non-magnetic coupling layer

9 magnetic layer
10 protection layer
11 lubricant layer
13 housing
16 magnetic recording medium
17 recording and reproducing head

【書類名】 図面 [DOCUMENT NAME] DRAWING

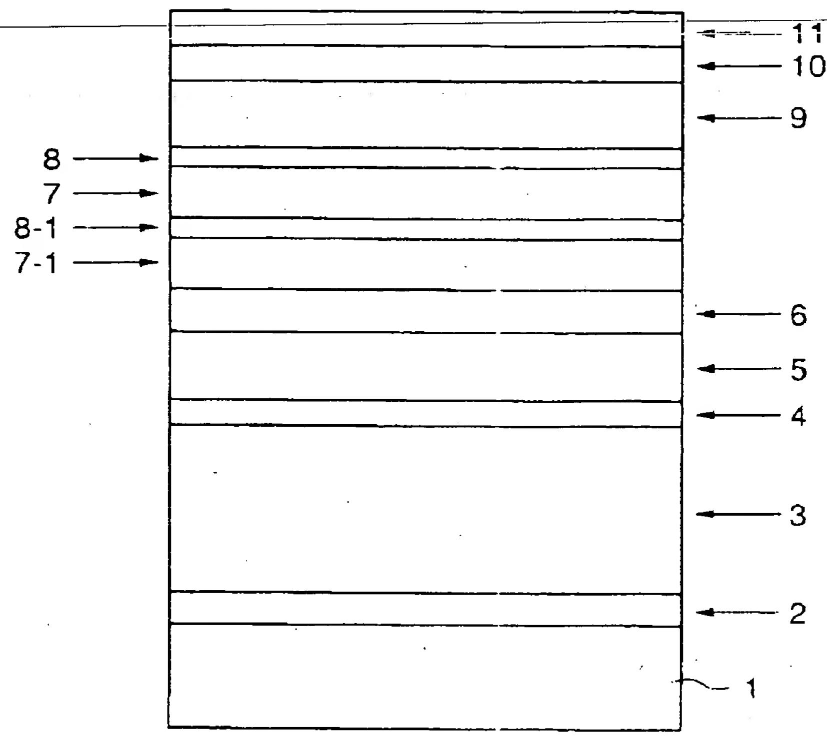
【図１】 FIG. 1: Cross sectional view showing an important part of a first embodiment of the magnetic recording medium according to the present invention

本発明になる磁気記録媒体の第1実施例の要部を示す断面図



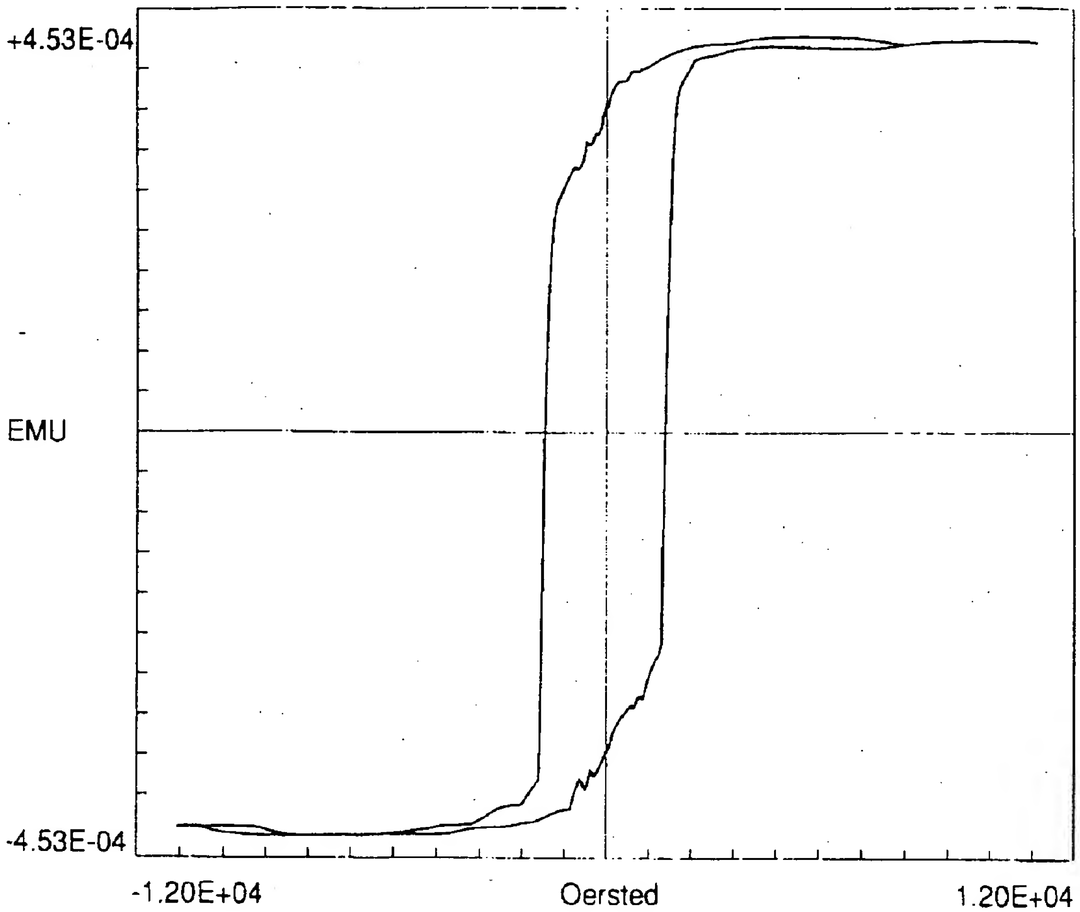
【図2】　FIG. 2: Cross sectional view showing an important part of a second embodiment of the magnetic recording medium according to the present invention

本発明になる磁気記録媒体の第2実施例の要部を示す断面図



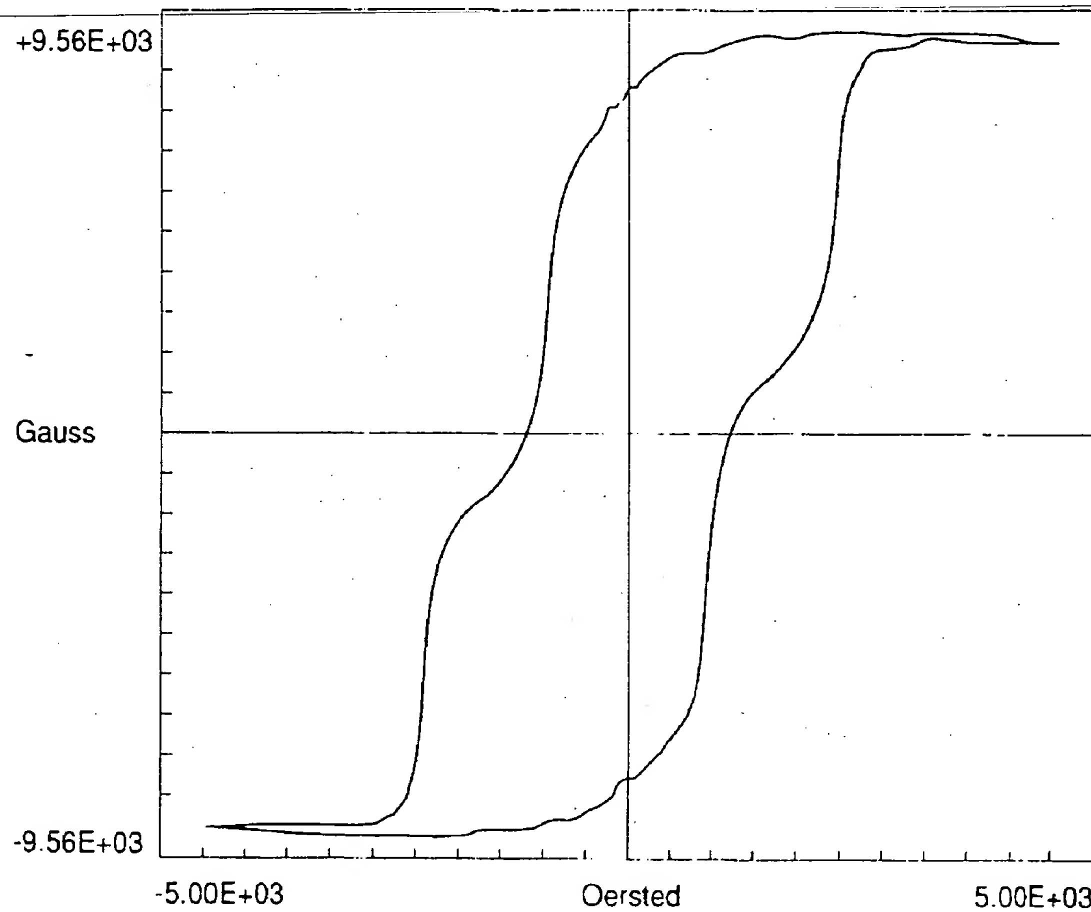
【図３】 FIG. 3: Diagram showing an in-plane magnetization curve of a single CoPt layer having a thickness of 10 nm on a Si substrate

Si基板上に形成された膜厚10nmの単一のCoPt層の面内磁気特性を示す図



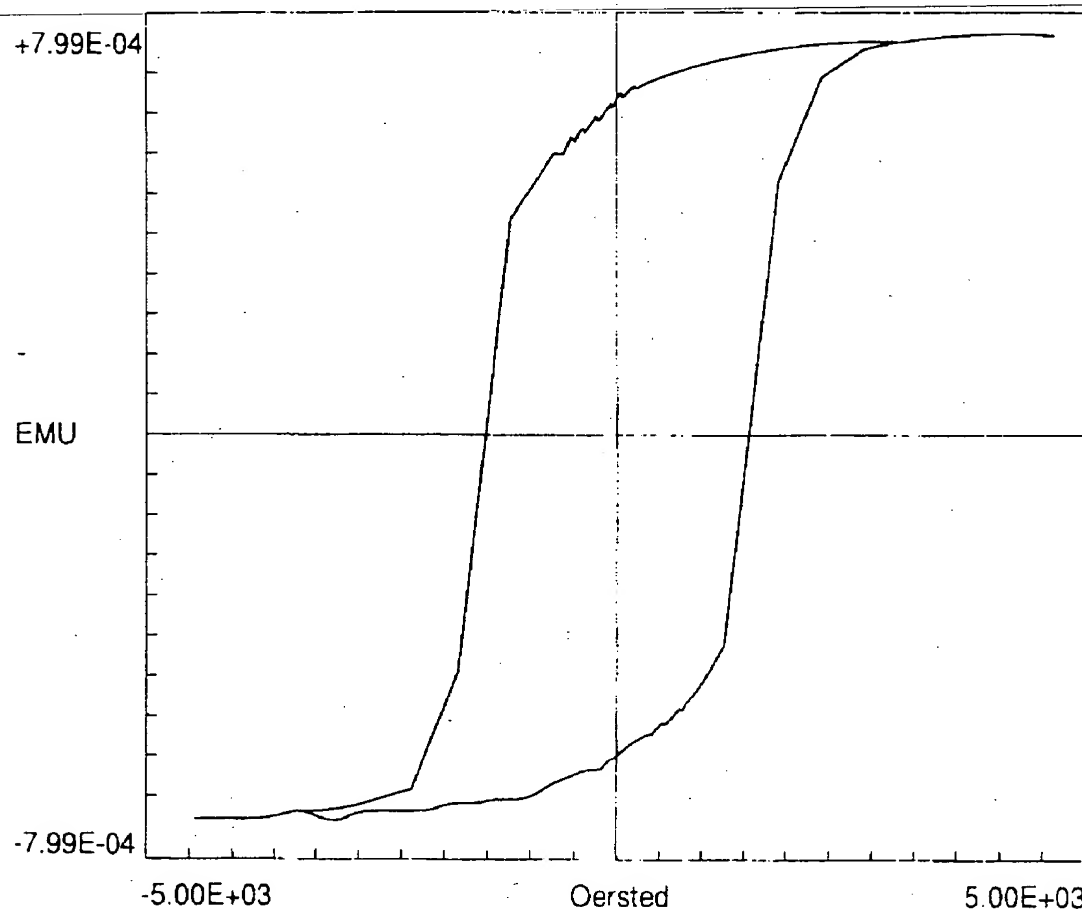
【図４】 FIG. 4: Diagram showing an in-plane magnetization curve of two CoPt layers separated by a Ru layer having a thickness of 0.8 nm

膜厚が0.8nmのRu層で分離された2つのCoPt層の面内磁気特性を示す図



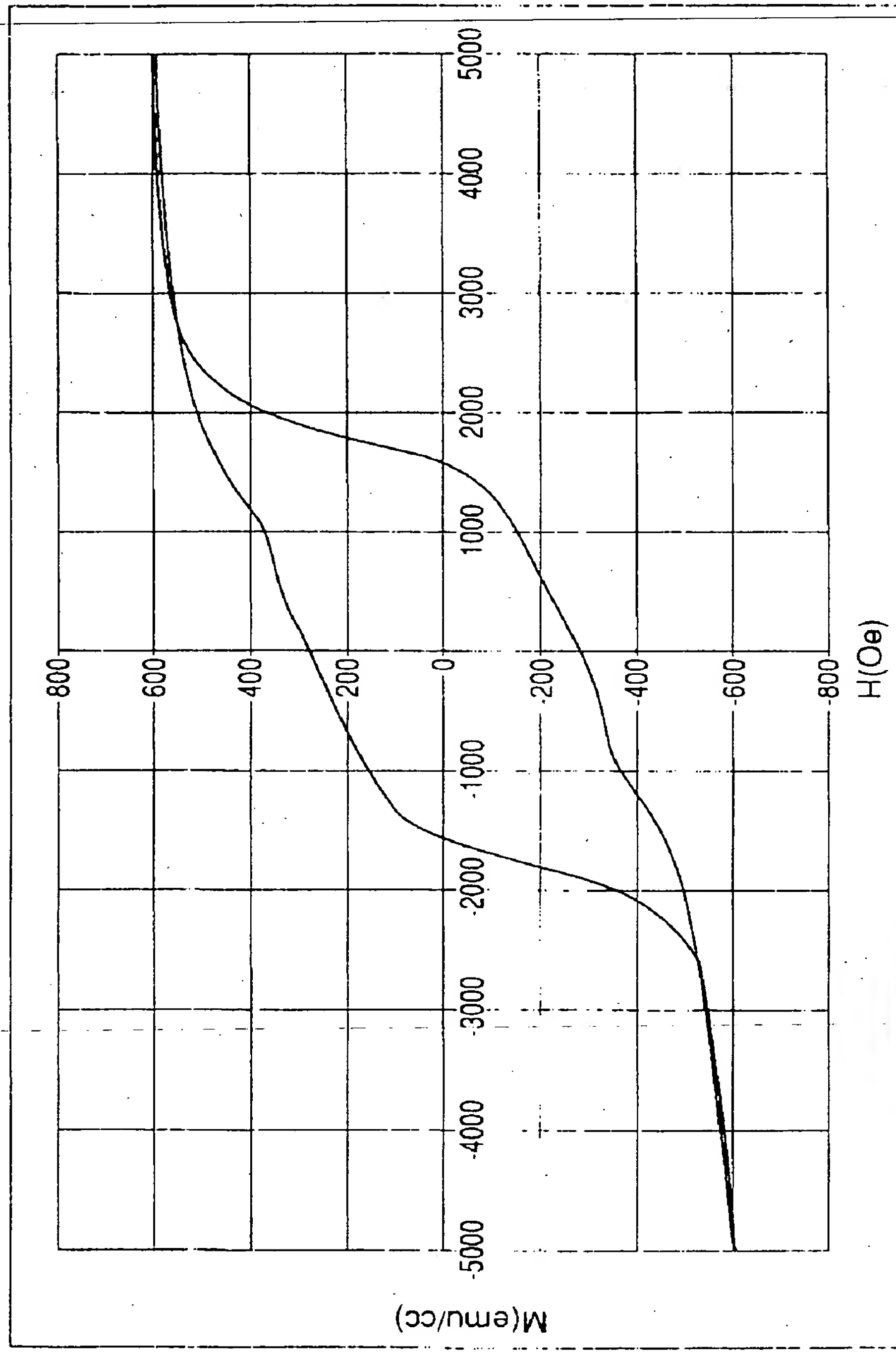
【図5】　FIG. 5: Diagram showing an in-plane magnetization curve of two CoPt layers separated by a Ru layer having a thickness of 1.4 nm

膜厚が1.4nmのRu層で分離された2つのCoPt層の面内磁気特性を示す図



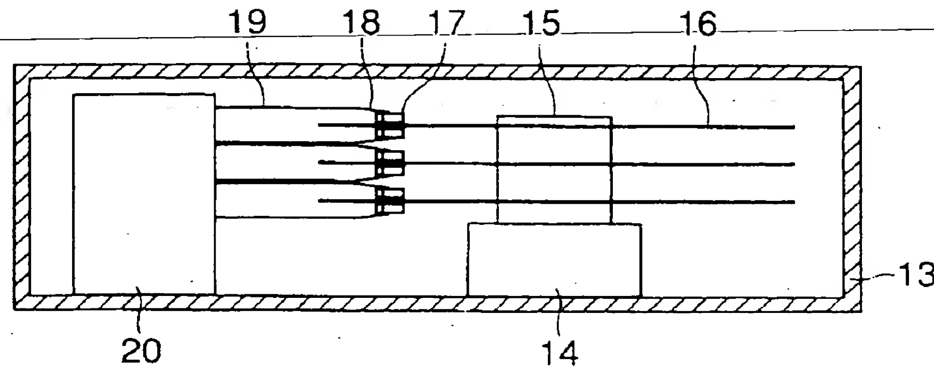
【図6】　FIG. 6: Diagram showing an in-plane magnetization curve two CoCrPt layers separated by a Ru having a thickness of 0.8 nm

膜厚が0.8nmのRu層で分離された2つのCoCrPt層の面内磁気特性を示す図



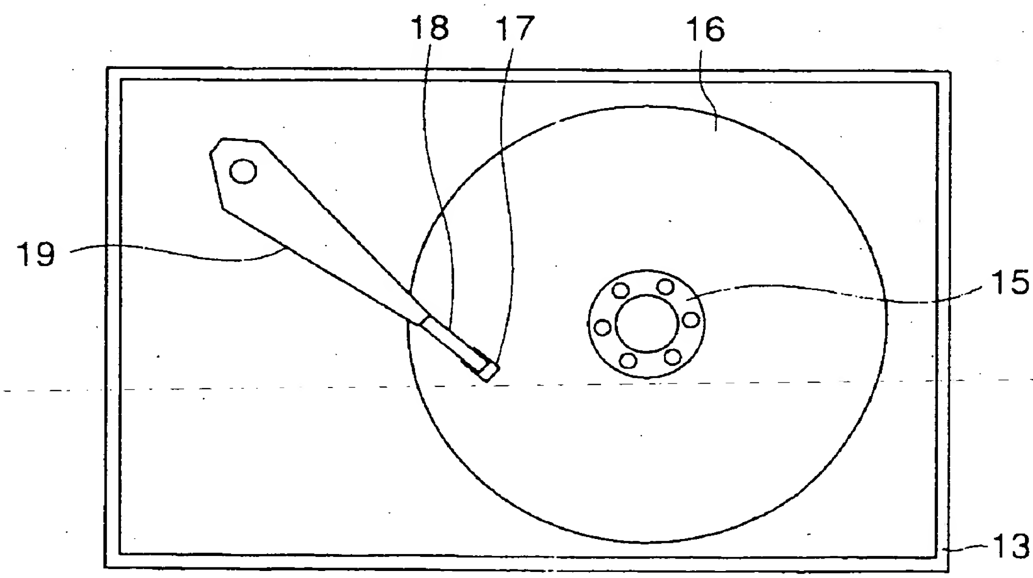
【図７】 FIG. 7: Cross sectional view showing an important part of an embodiment of the magnetic storage apparatus according to the present invention

本発明になる磁気記憶装置の一実施例の要部を示す断面図



【図８】 FIG. 8: Plan view showing the important part of the embodiment of the magnetic storage apparatus

磁気記憶装置の一実施例の要部を示す平面図



DOCUMENT NAME

ABSTRACT OF THE DISCLOSURE

ABSTRACT

OBJECT

The present invention relates to magnetic recording media and magnetic storage apparatuses, and an object is to improve the thermal stability of written bits and reduce the medium noise, so as to enable reliable high-density recording without introducing adverse effects on the performance of the magnetic recording medium.

MEANS OF SOLUTION

A magnetic recording medium is constructed to include at least one exchange layer structure, and a magnetic layer formed on the exchange layer structure, where the exchange layer structure includes a ferromagnetic layer and a non-magnetic coupling layer provided on the ferromagnetic layer and under the magnetic layer, and the ferromagnetic layer and the magnetic layer have antiparallel magnetizations.

SELECTED DRAWING

FIG. 1